

FIGURE 6.—Coal fields of Alaska (from Averitt, 1975).

coal, namely, free or surface moisture removed by exposure to air, and inherent moisture entrapped in the coal and removed by heating to 220°F.

noneconomic.—Not capable of profitable production or extraction. Coal classified as *noneconomic* may be reported in other occurrences. See *other occurrences, noneconomic coal*, p. 27,

original.—The amount of coal resources in the ground before production.

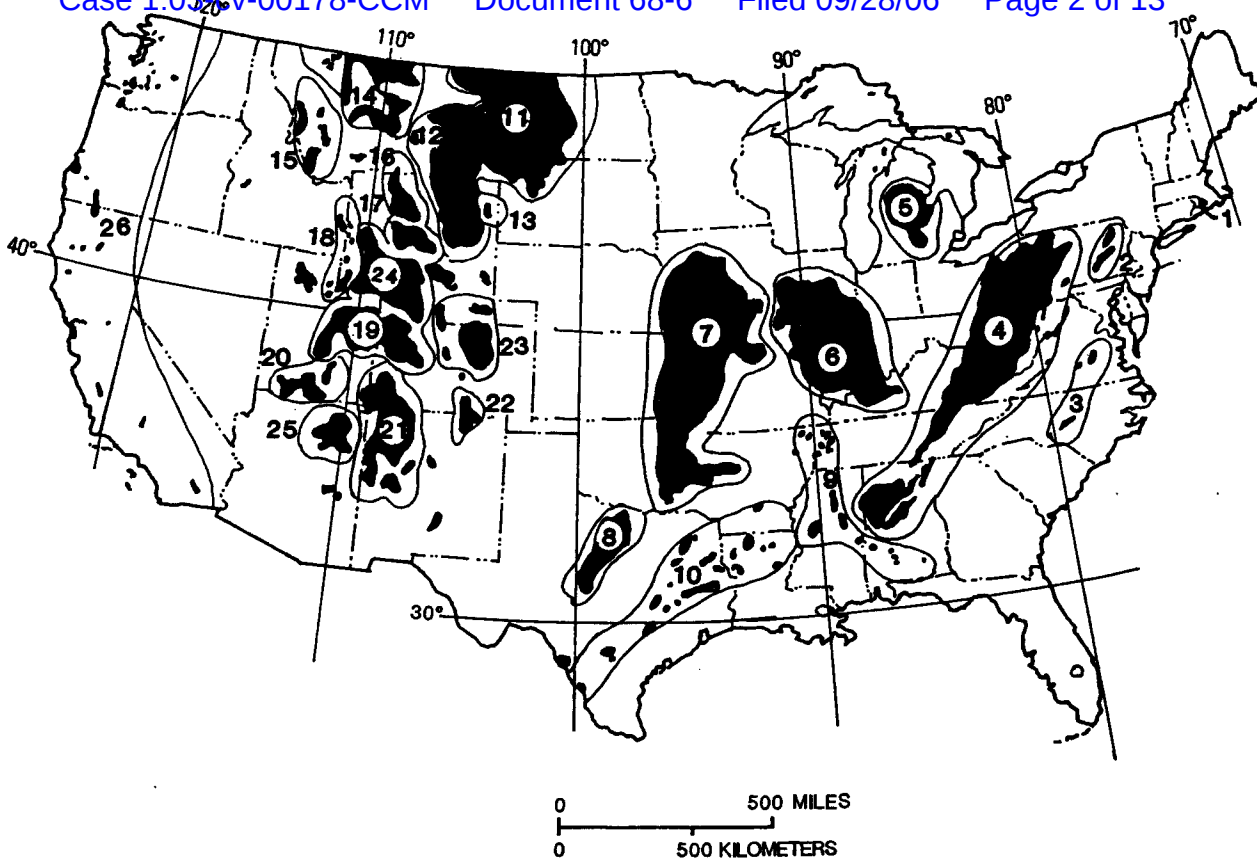
original resources.—See *Original Resources*, p. 19; and *original resources*. (See also *original resources*, p. 27; and figs. 1, 2, and 3.)

other occurrences.—Coal in the ground that is excluded from classification as coal resources. Includes anthracite and bituminous coal less than 14 inches thick, subbituminous coal and lignite less than 30 inches thick, and any coal more than 6,000 feet deep unless it is currently being mined. May include coal that contains more than 33 percent ash. (See *other occurrences, noneconomic coal*, p. 27; and figs. 1 and 2.)

overburden.—Rock including coal and (or) unconsolidated material that overlies a specified coal bed. *Overburden* is reported in feet and (or) meters and used to classify the depth to an underlying coal bed.

partial or incomplete measurement of coal thickness.—A determination of an incomplete coal thickness at a point of measurement.

Discussion: Measurements of coal thicknesses that are incomplete because of (1) near surface slumping of coal and overlying beds, (2) weathering, (3) a drill hole not penetrating the entire coal bed, (4) identified planar erosion of top part of coal bed, or (5) removal of most of a coal bed by a stream channel are to be treated as points of measurement from which circles of reliability are to be constructed. A geologist must decide whether each measurement is complete or incomplete. The thickness of coal at places where a measurement is deemed incomplete shall be located on the coal bed map by the number of feet and inches actually measured followed by a plus sign to indicate that only a part of the bed was measured. Thus, incomplete measurements define measured coal of a stated minimum thickness. If other thickness data are available to show by isopaching that a coal thickness is incomplete at a point of measurement, the isopached total thickness at the point of measurement should be used to determine the average thickness for the tonnage



EXPLANATION

- | | |
|--------------------------------|-----------------------|
| 1 Rhode Island Meta-anthracite | 14 North Central |
| 2 Pennsylvania Anthracite | 15 Tertiary lake beds |
| 3 Atlantic coast | 16 Bighorn |
| 4 Appalachian | 17 Wind River |
| 5 Northern | 18 Hams Fork |
| 6 Eastern Interior | 19 Uinta |
| 7 Western Interior | 20 Southwestern Utah |
| 8 Southwestern | 21 San Juan River |
| 9 Mississippi-Alabama | 22 Raton Mesa |
| 10 Texas-Louisiana | 23 Denver |
| 11 Fort Union | 24 Green River |
| 12 Powder River | 25 Black Mesa |
| 13 Black Hills | 26 Pacific |

FIGURE 7.—Coal regions of the conterminous United States (modified from Trumbull, 1960.)

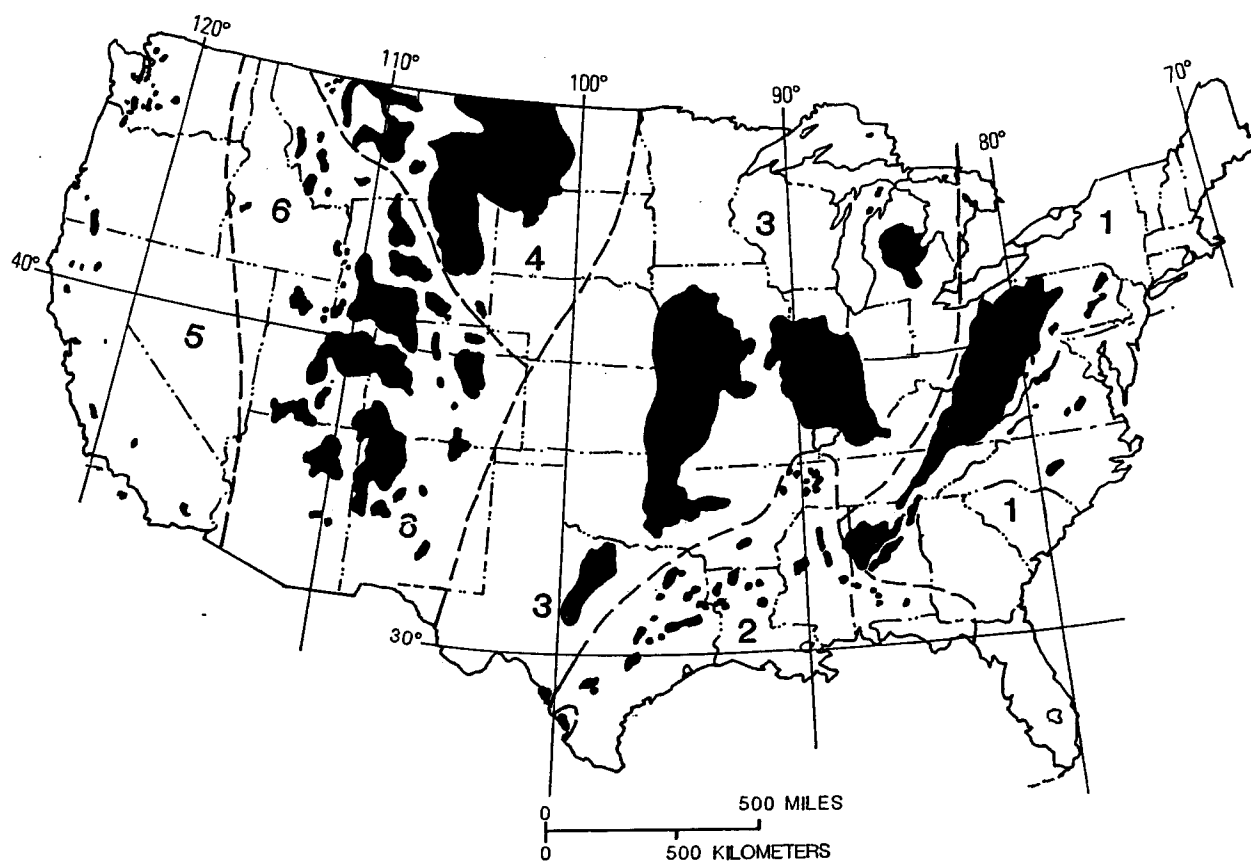
estimates of measured, indicated, and inferred categories. In those places where the coal bed cannot be isopached, the partial thickness of coal should be used as the thickness for estimating tonnages. See point of measurement.

parting.—A layer or stratum of non-coal material in a coal bed which does not exceed the thickness of coal in

either the directly underlying or overlying benches. (See specific instruction No. 3, p. 34.)

parts per million (ppm).—A method of stating content of a substance in coal. One *ppm* equals 0.001 percent, or 0.000001.

point of measurement.—The exact location on an outcrop, in a trench, in mine workings, or in a drill hole



EXPLANATION

- | | |
|------------|-------------------------|
| 1 Eastern | 4 Northern Great Plains |
| 2 Gulf | 5 Pacific Coast |
| 3 Interior | 6 Rocky Mountains |

FIGURE 8.—Coal provinces of the conterminous United States (modified from Trumbull, 1960.)

where a coal bed is measured for thickness and (or) sampled for analysis. The surface position of a *point of measurement* must be located precisely on a map so that its geodetic position can be determined. The altitude of a subsurface *point of measurement* can be determined from cores, lithologic logs, mine workings, and also can be determined from a geophysical log of a drill hole or well if, in the opinion of a geologist or geophysicist, the log is of good quality. See *partial or incomplete measurement of coal thickness*.

point of observation.—Place on an outcrop where a coal bed is visible or where evidence indicates that a coal bed could be measured or examined by trenching or digging a pit. Points of observation are used to verify the existence of a coal bed, and apparent

similarity and (or) difference of a coal bed's thickness as to thickness at points of measurement. They also can be used to confirm the position of a coal outcrop on a geologic map and to support the measured, indicated, and inferred classification of a coal bed; however, these points cannot be used without actual measurements to classify a resource body.

production.—The coal that has been extracted from a mine for a specified period. *Production* may be reported for a mine or larger area such as a coal field, region, province, basin, township, quadrangle, state, nation, and (or) the world. Production in the United States is usually reported in short tons; most other nations report production in metric tons.

proximate analysis.—In coal, the determination by

TABLE 1.—Classification of coals by rank ^{A, 1}

Class	Group	Fixed Carbon Limits, percent (Dry, Mineral-Matter-Free Basis)		Volatile Matter Limits, percent Dry, Mineral-Matter-Free Basis		Calorific Value Limits BTU per pound (Moist, ^B Mineral-Matter-Free Basis)		Agglomerating Character
		Equal or Greater Than	Less Than	Greater Than	Equal or Less Than	Equal or Greater Than	Less	
I. Anthracite [*]	1. Meta-anthracite	98	—	—	2	—	—	} nonagglomerating
	2. Anthracite	92	98	2	8	—	—	
	3. Semianthracite ^C	86	92	8	14	—	—	
II. Bituminous	1. Low volatile bituminous coal	78	86	14	22	—	—	} commonly agglomerating ^E
	2. Medium volatile bituminous coal	69	78	22	31	—	—	
	3. High volatile A bituminous coal	—	69	31	—	14 000 ^D	—	
	4. High volatile B bituminous coal	—	—	—	—	13 000 ^D	14 000	} agglomerating
	5. High volatile C bituminous coal	—	—	—	—	11 500	13 000	
		—	—	—	—	10 500	11 500	
III. Subbituminous	1. Subbituminous A coal	—	—	—	—	10 500	11 500	} nonagglomerating
	2. Subbituminous B coal	—	—	—	—	9 500	10 500	
	3. Subbituminous C coal	—	—	—	—	8 300	9 500	
IV. Lignite	1. Lignite A	—	—	—	—	6 300	8 300	} nonagglomerating
	2. Lignite B	—	—	—	—	—	6 300	

^AThis classification does not include a few coals, principally nonbanded varieties, which have unusual physical and chemical properties and which come within the limits of fixed carbon or calorific value of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 percent dry, mineral-matter-free fixed carbon or have more than 15 500 moist, mineral-matter-free British thermal units per pound.

^BMoist refers to coal containing its natural inherent moisture but not including visible water on the surface of the coal.

^CIf agglomerating, classify in low-volatile group of the bituminous class.

^DCoals having 69 percent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of calorific value.

^EIt is recognized that there may be nonagglomerating varieties in these groups of the bituminous class, and there are notable exceptions in the high-volatile C bituminous group.

¹ASTM, 1981, p. 215.

^{*}Modified from ASTM, 1981.

prescribed methods of moisture, volatile matter, fixed carbon (by difference), and ash. Unless specified, proximate analyses do not include determinations of sulfur or phosphorous or any determinations other than those named. Proximate analyses are reported by percent and on as-received, moisture-free, and moisture- and ash-free bases.

quality.—An informal classification of coal relating to its suitability for use for a particular purpose.

Discussion: Most coal is used as a source of heat or energy, but coal is or will be used in making petrochemicals, metallurgical coke, synthetic gas, and synthetic liquid fuel. Factors considered in judging a coal's quality are based on, but not limited to, heat value; content of moisture, ash, fixed carbon, phosphate, silica, sulfur, major, minor and trace elements; coking and petrologic properties; and

organic constituents considered both individually and in groups. The individual importance of these factors varies according to the intended use of the coal. Therefore, any designation of "high-quality coal," "moderate-quality coal," or "low-quality coal" should plainly indicate the intended or optimum use or uses and is inappropriate without such documentation.

quantity.—Refers to the amount or tonnage of coal.

Quantity should be reported in short or metric tons.

rank.—The classification of coals according to their degree of metamorphism, progressive alteration, or coalification (maturation) in the natural series from lignite to anthracite.

Discussion: Classification is made on the basis of analysis of coal in accordance with table 1. The *rank* of coal can be used to infer the approximate dry,

mineral-matter-free heat value, fixed carbon, and volatile matter in a coal, because the amounts of the constituents vary little within each coal rank. (See table 1; and *rank calculation*, p. 28.)

rank calculation.—The determination of the rank of a coal. Such determination must use the instructions given under *rank calculation*, p. 28.

recoverable coal.—The coal that is or can be extracted from a coal bed during mining. The term “recoverable” should be used in combination with “resources” and not with “reserves.”

recovery percent.—The percentage of coal extracted from a bed where the total tonnage originally in the bed is equal to 100 percent.

recovery factor.—The estimated or actual percentage of coal that can be or was extracted from the coal originally in a bed or beds for an area, mine, district, field, basin, region, province, township, quadrangle, county, state, political province, nation, and (or) the world. See *recovery factor method*, p. 28.

reliability categories.—Categories based on distance from points of measurement and (or) sampling. The measured, indicated, inferred, and hypothetical resource categories, as defined, indicate the relative reliability of tonnage estimates as related to distance from points of thickness control of particular parts of a coal deposit. The *reliability categories* are not indicative of the reliability of the basic data (that is, the accuracy of coal measurements, or the accuracy of location of the coal outcrop). It is assumed that all basic data used in resource estimation have been judged reliable by the estimator and that unreliable data have been discarded. (See fig. 4.)

reserves.—Virgin and (or) accessed parts of a coal reserve base which could be economically extracted or produced at the time of determination considering environmental, legal, and technologic constraints. The term *reserves* need not signify that extraction facilities are in place or operative. *Reserves* include only recoverable coal; thus, terms such as “extractable reserves” and “recoverable reserves” are redundant and are not a part of this classification system. (See figs. 1 and 3; and *reserves*, p. 30.)

Discussion: *Reserves* can be categorized as measured and indicated, as underground or surface minable, by thickness of overburden, by thickness of coal in the bed, and by various quality factors. The term “economic reserves” is not to be used because *reserves* by definition are economic. *Reserves*, which are derived from reserve base coal, exclude coal thinner or deeper than that classified as reserve

base unless such coal is currently mined. See general guideline No. 7, p. 32.

MANDATORY SUBDIVISIONS:

A. Indicated Reserves and Indicated Marginal Reserves.—Categories of virgin reserves having a moderate degree of geologic assurance. See *indicated and marginal reserves*. (See also *reserves*, p. 30; and figs. 1 and 3.)

B. Inferred Reserves and Inferred Marginal Reserves.—Categories of virgin reserves having a low degree of geologic assurance. See *inferred reserves and marginal reserves*. (See also *reserves*; p. 30; and figs. 1 and 3.)

C. Measured Reserves and Measured Marginal Reserves.—Categories of accessed and virgin coal reserves having the highest degree of geologic assurance. See *measured reserves and marginal reserves*. (See also figs. 1 and 3.)

OPTIONAL SUBDIVISIONS:

A. Reserves and Marginal Reserves.—*Reserves* may be divided into subcategories other than those heretofore defined. These subcategories may be differentiated, for example, by ash and sulfur content, and heat value; by types or varieties of coal such as boghead or cannel coal; by usage such as metallurgical, petrochemical, and synthetic fuel types; by mineral ownership such as State, Federal, Indian, or private ownership; by Federal coal underlying private surface ownership; and by reserves and restricted reserves underlying State or national parks, monuments, forests, grasslands; military and naval reservations, alluvial valley floors, steep slopes, lakes and large rivers, and environmentally protected areas.

1. Restricted Reserves and Restricted Marginal Reserves.—Those parts of any reserve category that are restricted or prohibited by laws or regulations from extraction by underground and (or) surface mining.

Discussion: For example, coal in a national park may meet all the physical, chemical and economic requirements of a reserve but is prohibited from extraction. The assignment to a restricted category may be either temporary or permanent; however, because laws and regulations can be repealed or changed, such coal should be separately distinguished, and tonnage estimates recorded as a restricted reserve. Locally, a specific regulation or law might prohibit one method of mining and allow or not specify other methods. In such a circumstance, the coal would be restricted

from mining by the prohibited method and tonnage estimates would be so recorded. In other circumstances, other methods would be unrestricted, and tonnage estimates would be reported accordingly.

The separation of coal reserves into the many different subcategories listed above and other subcategories not listed in this text is desirable and encouraged. All subcategories not listed should be defined clearly and explicitly so that other resource specialists and the public will not be confused.

reserve base.—Those parts of the identified resources that meet specified minimum physical and chemical criteria related to current mining and production practices, including those for quality, depth, thickness, rank, and distance from points of measurement. (See *reliability categories*; and figs. 2 and 3.) The *reserve base* is the in-place demonstrated (measured plus indicated) resource from which reserves are estimated. The *reserve base* may encompass those parts of a resource that have a reasonable potential for becoming economically available within planning horizons beyond those that assume proven technology and current economics. The *reserve base* includes those resources that are currently economic (reserves), marginally economic (marginal reserves), some of those that are currently subeconomic (subeconomic resources), and some of the resources that have been or will be lost-in-mining but whose attributes indicate possible future recovery. The term “geologic reserve” has been applied by others to the reserve base category, but it also may include the inferred reserve base category; it is not a part of this classification system. (See *reserve base*, p. 29; and figs. 2 and 3.)

reserve base, inferred.—The in-place part of an identified resource from which inferred reserves and inferred marginal reserves are estimated. Quantitative estimates are based largely on knowledge of the geologic character of a coal deposit for which there are no samples or measurements. The estimates are based on an assumed continuity beyond the reserve base for which there is geologic evidence. (See figs. 2 and 3.)

resources.—Naturally occurring concentrations or deposits of coal in the Earth’s crust, in such forms and amounts that economic extraction is currently or potentially feasible. (See *resources*, p. 30; and figs. 1, 2, and 3.)

MANDATORY SUBDIVISIONS:

A. Hypothetical Resources.—See Undiscovered Resources (p. 20). (See also *hypothetical resources*, p. 25; and figs. 1, 2, and 3.)

B. Identified Resources.—Resources whose location, rank, quality, and quantity are known or estimated from specific geologic evidence. (See *identified resources*, p. 25). Identified coal resources include economic, marginally economic, and subeconomic components. To reflect varying distances from points of control or reliability, these subdivisions can be divided into demonstrated and inferred, or preferably into measured, indicated, and inferred. (See *identified resources*, p. 25; and figs. 1, 2, and 3.)

Discussion: *Identified resources* may be accessed and (or) in bodies of virgin coal which are assigned to resource and reserve base subcategories on the basis of geologic evidence from maps, samples, drill holes, wells, mine records, and fieldwork. Specific evidence must include data on the location, thickness of overburden, distance from points of measurement or sampling, and extent and thicknesses of the resource bodies. Evidence about quality and rank may be determined from analyses of samples collected from the resource bodies or may be inferred by projection of analytical data obtained elsewhere in the body or from adjacent bodies. An identified resource body may contain reserves, marginal reserves, inferred reserves, inferred marginal reserves, reserve base, inferred reserve base, demonstrated resources, measured resources, indicated resources, inferred resources, subeconomic resources and inferred subeconomic resources. (See figs. 1, 2, and 3.)

C. Indicated Resources.—Identified bodies of virgin coal having a moderate degree of geologic assurance. See *indicated*. (See also *indicated resources*, p. 26; and figs. 1, 2, and 3.)

D. Inferred Resources.—Identified bodies of virgin coal having a low degree of geologic assurance. See *inferred resources*. (See also *inferred resources*, p. 26; and figs. 1, 2, and 3.)

E. Measured Resources.—Accessed and virgin demonstrated resources having a high degree of geologic assurance. (See *measured resources*, p. 27; and figs. 1, 2, and 3.)

F. Original Resources.—The amount of coal in-place before production. Where mining has occurred, the total of *original resources* is the sum of the identified resources, undiscovered resources, coal produced, and coal lost-in-mining. (See *original resources*, p. 27; and figs. 1, 2, and 3.)

G. Remaining Resources.—The resources in the

ground in a mine, area, field, basin, region, province, county, state, and (or) nation after some mining. The term does not include coal lost-in-mining unless such coal can be considered potentially recoverable. *Remaining resources* may be divided into categories such as remaining economic, marginally economic, subeconomic, measured, indicated, inferred, identified, and undiscovered (hypothetical and speculative) resources or other types of resources. (See optional subdivisions, below; and figs. 1, 2, and 3.) The total remaining resources are the sum of the remaining identified and undiscovered resources as of the date of the estimate.

H. Subeconomic Resources.—That part of identified (demonstrated) resources that does not meet the economic criteria of reserves and marginal reserves. See *resources* and *economic*. (See also *subeconomic resources*, p. 31; and figs. 1 and 2.)

I. Inferred Subeconomic Resources.—That part of identified (inferred) resources that does not meet the economic criteria of inferred reserves or inferred marginal reserves. See *resources* and *economic*. (See also *subeconomic resources*, p. 31; and figs. 1 and 2.)

J. Speculative Resources.—See Undiscovered Resources (below). (See also *speculative resources*, p. 30; and figs. 1, 2 and 3.)

K. Undiscovered Resources.—*Undiscovered resources*, the existence of which is only postulated, comprise deposits that are either separate from or are extensions of identified resources. *Undiscovered resources* may be postulated in deposits of such quality, rank, quantity, and physical location as to render them economic, marginally economic, or subeconomic. To reflect varying degrees of geologic certainty, *undiscovered resources* may be subdivided into two parts as follows. (See *undiscovered resources*, p. 31.)

1. Hypothetical Resources.—A class of undiscovered resources that are either similar to known coal deposits which may be reasonably expected to exist in the same coal field or region under analogous geologic conditions or are an extension from inferred resources. In general, *hypothetical resources* are in the central parts of broad areas of coal fields where points of sampling and measurement and evidence for thickness and existence is from distant outcrops, mine workings, drill holes, and wells. If exploration confirms the existence of hypo-

thetical resources and reveals enough information about their quality, quantity, and rank, they will be reclassified as identified resources.

2. Speculative Resources.—A class of undiscovered resources that may occur either in known types of deposits in favorable geologic settings where coal deposits have not been discovered or in types of deposits as yet unrecognized for their economic potential. If exploration confirms the existence of speculative resources and reveals enough information about their quality, quantity, and rank, they will be reclassified as identified resources.

OPTIONAL SUBDIVISIONS:

Resources may be divided into subcategories, for example, on the basis of ash content, sulfur content, and heat value; type or variety of coal such as boghead or cannel coal; usage such as metallurgical, petrochemical, and synthetic fuel types; resources underlying specified lands owned by State governments, the Federal Government, or private interests; by restricted resources underlying State or national parks, monuments, forests, grasslands; military, naval, and Indian reservations; and alluvial valley floors, steep slopes, lakes and large rivers, and environmentally protected areas.

A. Restricted Resources.—Those parts of any resource category that are restricted or prohibited from extraction by laws or regulations.

Discussion: Restricted resources meet all requirements of coal classified as resources, except that they are restricted from extraction by law or regulation. The assignment to a restricted category may be either temporary or permanent, but, because laws and regulations can be repealed or changed, such coal should be separately distinguished and tonnage estimates recorded as restricted resources.

The division of coal resources into the many different categories described heretofore and into other categories not differentiated in the text is desirable and encouraged. Many requests for information about resources are received by coal resource specialists and are unanswerable because the scopes of the systems of classification used in the past were too limited. Persons and institutions classifying resources are, therefore, encouraged to use initiative in defining and developing additional classes of coal resources.

restricted reserves.—See optional subdivisions of reserves.

restricted resources.—See optional subdivisions of resources.

roof.—Stratigraphically, in underground mining the rock immediately overlying a coal bed. Where a bed is overturned, the stratigraphic *roof* is the mining floor.

sample.—A representative fraction of a coal bed collected by approved methods, guarded against contamination or adulteration, and analyzed to determine the nature; chemical, mineralogic, and (or) petrographic composition; percentage or ppm content of specified constituents; heat value; and possibly the reactivity of the coal or its constituents.

Discussion: Some samples are also collected so that fossil remains can be ascertained and physical, magnetic, or other geophysical properties can be determined, tested, observed, or analyzed. All samples should be accompanied by a description of the *sample*, including location, thickness of coal, and stratigraphic relationship to other rocks.

TYPES OF SAMPLES:

A. **as-received sample.**—A sample of coal as it is received at a laboratory.

B. **bed or channel sample.**—A sample of coal collected from a channel cut perpendicular to the stratification.

Discussion: This type of sample is used to ascertain the chemistry, rank of coal, mineralogy, petrography, and geophysical and physical properties of coal. Instructions for this type of sampling are contained in Geological Survey Circular 735 (Swanson and Huffman, 1976, p. 2).

C. **bench sample.**—A sample of a subdivision and (or) layer of a coal bed separated from other subdivisions by partings of non-coal rock.

Discussion: The term *bench sample* does not apply to coal lithotypes such as vitrinite and exinite as used by petrologists.

D. **blend pile sample.**—A sample of coal collected from the blend-pile of a processing plant or a utilization facility such as a powerplant or steel mill.

E. **breaker sample.**—A sample of coal broken or crushed in a breaker plant. A *breaker sample* is usually collected prior to cleaning of coal.

F. **cleaned coal sample.**—A sample of coal collected after use of a cleaning procedure.

G. **core sample.**—A sample of coal recovered

from a core which was obtained at depth by a coring device in a drill hole.

H. **cutting sample.**—A sample of coal taken from the cuttings returned during drilling.

Discussion: Cutting samples are not recommended because many comparisons with properly or conventionally collected samples indicate they are rarely representative.

I. **delivered coal sample.**—A sample of coal collected from a shipment that is being or will be delivered to a user.

J. **grab sample.**—A sample, commonly a single piece, selected from a coal bed, tippie, preparation plant, blend pile, conveyor belt, or coal car.

Discussion: Grab samples are not recommended because many comparisons with properly collected samples indicate they are rarely representative.

K. **mine sample.**—A sample of coal collected from a mine, generally from an underground working face or from a strip-wall face.

L. **run of mine or mine run sample.**—Generally the same as a *tippie sample*.

M. **tippie sample.**—A sample of coal collected at a mine tippie.

seam.—A bed of coal lying between a roof and floor.

This term is not to be used in place of "coal bed" in reports of the U.S. Geological Survey.

short ton.—A unit of weight equal to 2,000 pounds; 0.9071847 metric ton, tonne, or megagram; 0.8928571 long ton.

specific gravity of coal.—The ratio of the mass of a unit volume of coal to the mass of an equal volume of water at 4°C.

Discussion: The *specific gravity of coal* varies considerably with rank and with differences in ash content. The values shown in table 2 are close to the average specific gravities of unbroken or unmined coal in the ground (in situ) for the four major rank categories and are to be used in preparing U.S. Geological Survey estimates of coal resources and reserves.

Persons associated with individual mining operations sometimes use lower specific gravity factors to allow for anticipated losses in extraction. Such usage may be suitable for specific mine areas but is not recommended for use in general reports because the recoverability of coal varies greatly between areas, beds, mining methods, and mine operators.

speculative.—Lowest degree of geologic assurance. Estimates of rank, thickness, and extent are based on

TABLE 2.—Average specific gravity and average weight of unbroken coal per unit volume of different ranks

Rank	Specific gravity	Weight of unbroken coal per unit volume					
		Short tons per acre-foot	Short tons per acre-inch	Metric tons per acre-foot	Short tons per square mile-foot	Metric tons per square mile-foot	Metric tons per square hectometer-meter
Anthracite and semianthracite	1.47	2,000	166.6	1,814	1,280,000	1,160,960	14,700
Bituminous coal	1.32	1,800	150	1,633	1,152,000	1,045,120	13,200
Subbituminous coal	1.30	1,770	147.5	1,605	1,132,800	1,027,200	13,000
Lignite	1.29	1,750	145.8	1,588	1,120,000	1,016,320	12,900

assuming the existence of known types of coal deposits in favorable geologic settings or on assuming the existence of unknown types of deposits as yet unrecognized for their economic potentials. Tonnages are estimated by assuming thickness of coal, overburden, extent, and rank to a specified depth. There are geologic evidence sites but no measurement sites in areas of speculative coal. Used as a modifier to resource terms. See Hypothetical Resources, p. 20; Speculative Resources, p. 20; and Undiscovered Resources, p. 20. (See also figs. 1, 2, and 3.)

speculative resources.—See Speculative Resources, p. 20. (See also *speculative resources*, p. 30; and figs. 1, 2, and 3.)

square hectometer-meter (hm²-m).—A metric unit of the volume of coal that covers 1 square hectometer at a thickness of 1 meter; 10,000 cubic meters; 10 cubic dekameters; 0.010 square kilometer-meter; 13,079.51 cubic yards; 8.107132 acre-feet; 0.0126674 square mile-foot. The weight of coal in this volume varies according to rank. (See table 1.)

square kilometer.—1,000,000 square meters; 100 hectares; 247.10538 acres; 1,195,990 square yards; 10,763,910 square feet.

square kilometer-meter (km²-m).—The volume of coal (1,000,000 cubic meters; 100 square hectometer-meters or 100 hectare-meters; 1,307,950.6 cubic yards; 35,314,667.0 cubic feet) that covers 1 square kilometer at a thickness of 1 meter. The weight of coal varies according to the rank. (See table 2.)

square mile.—27,878,400 square feet; 3,097,600 square yards; 2,589,988.1 square meters; 258.99881 hectares; 640 acres; 2.5899881 square kilometers.

square mile-foot.—The volume of coal (27,878,400 cubic feet; 789,428.38 cubic meters; 1,032,533.33 cubic yards) that covers 1 square mile to a thickness of 1 foot. The weight of coal varies according to the rank. (See table 2.)

strip or stripping ratio.—The amount of overburden that must be removed to gain access to a unit amount of coal.

Discussion: A *stripping ratio* may be expressed as (1) thickness of overburden to thickness of coal, (2) volume of overburden to volume coal, (3) weight of overburden to weight of coal, or (4) cubic yards of overburden to tons of coal. A *stripping ratio* commonly is used to express the maximum thickness, volume, or weight of overburden that can be profitably removed to obtain a unit amount of coal.

strip or surface mining.—The extraction of coal by using surface mining methods such as area strip mining, contour strip mining, or open-pit mining. The overburden covering the coal is removed and the coal extracted using power shovels, front end loaders, or similar heavy equipment.

subbituminous coal.—A rank class of nonagglomerating coals having a heat value content of more than 8,300 Btu's and less than 11,500 Btu's on a moist, mineral-matter-free basis. This class of coal is divisible on the basis of increasing heat value into the subbituminous C, B, and A coal groups. (See table 1.)

subeconomic resources.—See **resources** and **economic**. (See also *subeconomic resources*, p. 31; and figs. 1, 2, and 3.)

sulfur content.—The quantity of sulfur in coal expressed in percent or parts per million. May be divided into the quantities occurring as inorganic (pyritic) sulfur, organic sulfur, and sulfate sulfur.

thickness categories.—The categories of thickness of coal beds employed in calculating, estimating, and reporting coal resources and reserves. (See *thickness of coal for resource calculations*, p. 31; and specific instruction No. 3, p. 34.)

ultimate analysis.—In coal, the determination by prescribed methods of the ash, carbon, hydrogen, nitrogen, oxygen (by difference), and sulfur contents. Quantities of each analyzed substance are reported by percentage for the following conditions: as-received, dried at 105°C, and moisture-and ash-free.

Discussion: The principal reason for the *ultimate analysis* is the classification of coals by rank, although it

is often used for commercial and industrial purposes when it is desirable to know the sulfur content. The *ultimate analysis* also is known as the "total analysis." This, however, is a misnomer because substances other than those noted above are not identified and quantified, such as trace elements, oxides, and rare gases.

underground mining.—The extraction of coal or its products from between enclosing rock strata by underground mining methods, such as room and pillar, longwall, and shortwall, or through in situ gasification.

undiscovered.—A category of virgin resources of coal having the lowest degree of geologic assurance. Category is divisible into the hypothetical and speculative categories. (See *hypothetical and speculative*.) Estimates are quantitative. There are no sample or measurement of coal thickness sites in areas of undiscovered coal. Used as a modifier to resources.

undiscovered resources.—See mandatory subdivisions of resources. (See also *undiscovered resources*, p. 31; and figs. 1, 2, and 3.)

vein.—A bed of coal lying between a distinct roof and floor. Term is not to be used in place of "coal bed" in reports of the U.S. Geological Survey.

virgin coal.—Coal that has not been accessed by mining. See *accessed*.

volatile matter.—In coal, those products, exclusive of moisture, given off as gas and vapor, determined by definite prescribed methods (ASTM, 1981, p. 184, D2361-66, D3761-79, D3175-77, D3176-74, D3178-73, and D3179-73).

CRITERIA FOR COAL RESOURCE CLASSIFICATION

Although not specifically noted, coal resources are classified in figures 1, 2, and 3 according to geologic assurances of existence and to the economic feasibility of recovery.

The degree of geologic assurance in this system of coal classification is determined from the interrelations of (1) proximity to or closeness of spacing of points where a coal bed is measured or sampled (reliability); (2) concepts, ideas, and models of the depth, rank, quality, thickness of coal, areal extent, depositional patterns and correlations of coal beds and enclosing rocks; and (3) knowledge of associated structural features as they control the distribution, extent, thickness, depth of burial, and metamorphism of coal resources. An understanding of these elements as they relate to the three

dimensional configurations of stratigraphic sequence is necessary to provide the highest degree of geologic assurance as to the existence and continuity or lack of continuity of specific coal beds.

The degree of economic feasibility is determined by interrelating the (1) thickness of coal (see specific instruction No. 3, p. 34); (2) thickness of overburden; (3) the rank and quality of coal as ascertained from analyses that may be from the same bed or adjacent beds and which may be projected on geologic evidence for several miles; (4) costs of mining, processing, labor, transportation, selling, interest, taxes, and demand and supply; (5) expected selling price; and (6) expected profits.

The thickness of overburden and the thickness of a coal bed are the primary factors controlling the feasibility of mining. Knowledge of the quantity of coal and rock that must be removed per unit of recovered coal, of the roof and floor conditions, and of the difficulty of separating coal from rock determine the mining method and the equipment chosen for the mining operation. The rank, purity, heat value, and selling price of the coal commonly dictate usage and marketability. Higher rank coals generally are judged more valuable than lower rank coals owing to greater heat values and chemical characteristics that are sought currently by the metallurgical and petrochemical industries. Economic variables that influence feasibility are price of coal, cost of equipment, mining, labor, processing, transportation, interest rates, and taxes. Supply and demand for coal also influence feasibility as do environmental laws, restrictions, judicial ratings, and political considerations. The relative value of coals may change markedly in the near future as the result of utilizing new techniques for converting coal to gas and or liquid fuels. Low-rank coals and coals containing pyrite that are currently of lower economic value may in the future be considered premium fuels for conversion processes.

The criteria for the principal classes of coal resources described hereafter are summarized in table 3 and are to be used in preparing all U.S. Geological Survey coal resource estimates from January 1, 1983, until further revised.

APPLICATIONS OF CRITERIA

The criteria are to be applied only to those deposits of coal that are currently or potentially feasible for economic extraction by underground mining, surface mining, and (or) in situ gasification methods. Coal beds that are thinner than 14 inches (35 cm; anthracite and

TABLE 3.—*Summary of coal resource criteria*

		Depth ¹ Feet (Meters)	Thickness ¹ Inches (Centimeters)
Identified and undiscovered resources:			
Anthracite and bituminous			
coal	-----	≤ 6,000 (1,800)	≥ 14 (35)
Subbituminous coal and			
lignite	-----	≤ 6,000 (1,800)	≥ 30 (75)
Reserve base and inferred reserve base:			
Anthracite and bituminous			
coal	-----	≤ 1,000 (300)	≥ 28 (70)
Subbituminous coal	-----	≤ 1,000 (300)	≥ 60 (150)
Lignite	-----	≤ 500 (150)	≥ 60 (150)
Reserves ² , marginal reserves, and inferred reserves ² :			
(Criteria same as reserve base and inferred reserve base but with factors based on engineering and economic analysis applied.)			
Subeconomic resources:			
Anthracite and			
bituminous	0-1,000 (300)	14 (35)-28 (70)	
coal	1,000 (300)-6,000 (1,800)	≥ 14 (35)	
Subbituminous			
coal	0-1,000 (300)	30 (75)-60 (150)	
	1,000 (300)-6,000 (1,800)	≥ 30 (75)	
Lignite			
	0-500 (150)	30 (75)-60 (150)	
	500 (150)-6,000 (1,800)	≥ 30 (75)	

¹The metric thicknesses shown in parentheses are not exact equivalents of the thicknesses shown in feet; for convenience, they have been rounded to the amounts shown.

²Includes some beds that are thinner and (or) deeper than the general criteria permit, but that are being mined currently.

bituminous) and 30 inches (75 cm; lignite and subbituminous) generally are excluded from resource consideration unless currently being mined. All coal beds deeper than 6,000 feet (1,800 m) are excluded. These limits are imposed as the result of consultations with geologists and mining engineers throughout the international coal community. In the United States, beds that contain more than 33 percent ash also are excluded; because of a shortage of energy in some countries, however, coal containing more than 33 percent ash is being mined and is classified as reserves.

Coal beds thinner or more deeply buried than the imposed limits have been mined locally at several places in the United States and are mined in other parts of the world; however, their extraction in the United States has generally not proven economic. Where such mining is taking place, the coal should be classed as a reserve and recorded at the time of assessment in the coal resource figures. With the few exceptions owing to current mining and similar future exceptions, the imposed limits should be adhered to. See general guideline No. 7, p. 32.

SPECIFIC CRITERIA

Note.—Specific criteria and glossary terms are cross-referenced within this report. To aid the reader, specific criteria, beginning below, are printed in ***boldface italics***, and glossary items, beginning on p. 5, are printed in ***boldface type***.

anthracite and bituminous coal reserves.—Tonnage estimates for these classes of coal are determined by summing the recoverable quantities of coal in the reserve base and are assigned to the following categories: (a) thickness of coal—28 to 42 inches (70 to 105 cm), 42 to 84 inches (105 to 215 cm), 84 to 168 inches (215 to 430 cm), more than 168 inches (> 430 cm); and (b) thickness of overburden—0 to 500 feet (0 to 150 m) and 500 to 1,000 feet (150 to 300 m). Tonnage estimates for the bituminous coal class may be divided into low-volatile, medium-volatile, high-volatile A, high-volatile B, and high-volatile C groups. Similarly, tonnage estimates for the anthracite class may be divided into meta-anthracite, anthracite, and semianthracite groups. Reserves assigned to these coal classes must be considered as economically producible at the time of classification, but facilities for extraction need not be in place and operative. See specific instruction No. 3, p. 34.

anthracite and bituminous coal inferred reserves.—Tonnage estimates for these classes of coal are determined by summing the recoverable quantities of coal in the inferred reserve base and are assigned to the same coal thickness and overburden thickness categories as anthracite and bituminous coal reserves. Inferred reserves must be considered as economically producible at the time of classification. Facilities for extraction need not be in place and operative.

anthracite and bituminous coal marginal and inferred marginal reserves.—Tonnage estimates for these classes of coal are determined by summing the marginally recoverable quantities of coal in the reserve base and in the inferred reserve base and are assignable to the same categories of thickness of coal and overburden described for anthracite and bituminous coal reserves. These classes of coal may be divided into the same rank groups as described for anthracite and bituminous coal reserves. Marginal and inferred marginal reserves must be considered uncertain as to economic producibility at the time of classification. Facilities for extraction need not be in place and operative.

anthracite and bituminous coal reserve base and inferred coal reserve base.—See *reserve base* for thickness of coal and thickness of overburden criteria.

anthracite and bituminous coal resources.—Tonnage estimates for these classes of coals are determined by summing the estimates for anthracite and bituminous coal identified and undiscovered resources (fig. 3). They are assignable to the same thickness categories as for anthracite and bituminous coal reserves with the addition of a 14–28 inch (35–70 cm) category (see specific instruction No. 3, p. 34), and the following overburden categories are to be recognized: 0 to 500 feet (0 to 150 m); 500 to 1,000 feet (150 to 300 m); 1,000 to 2,000 feet (300 to 600 m); 2,000 to 3,000 feet (600 to 900 m); and 3,000 to 6,000 feet (900 to 1,800 m). Tonnage estimates for the bituminous coal class may be divided into the low-volatile, medium-volatile, high-volatile A, high-volatile B, and high-volatile C groups, and tonnage estimates for the anthracite class may be divided into the meta anthracite, anthracite, and semianthracite groups.

cumulative depletion.—*Cumulative depletion* is summed from all coal extracted and lost-in-mining prior to the date of the estimate, which may be subdivided on the basis of rank and subrank (class and group) of coal, overburden class, thickness class, mining method, heat value, usage, time, cokeability, chemical constituents, and area of production.

cummulative production.—*Cummulative production* is summed from production from a mine, field, basin, region, province, state, or nation prior to the date of the estimate, which may be subdivided on the basis of rank and subrank (class and group) of coal, overburden class, thickness class, mining method, heat value, usage, time, cokeability, chemical constituents, and area of production.

demonstrated reserves and demonstrated marginal reserves.—Tonnage estimates for these categories of coal are the sum of the estimates for measured and indicated reserves and marginal reserves, respectively, which are the preferred usages. See Reserves and Marginal Reserves, p. 18.

demonstrated reserve base.—Tonnage estimates for this category of coal are determined by summing the estimates for the measured and indicated reserves bases. The *demonstrated reserve base* is the same as the “reserve base,” which is the preferred usage. See *reserve base*, p. 19).

demonstrated resources.—Tonnage estimates for this category are the sum of the estimates for the reserve base and subeconomic resources.

economic resources.—An informal term used by geologists to indicate their estimates of the coal resources that are potentially economic.

hypothetical resources.—Tonnage estimates for this category of resources are for (1) extensions of inferred resources (coal beyond a radius of 3 miles or 4.8 km from a point of measurement), and (2) regions where tonnage estimates are based on a knowledge of the geologic character of coal. *Hypothetical resources* include coal that is 14 inches (35 cm) or more thick (anthracite and bituminous coal) and 30 inches (70 cm) or more thick (subbituminous coal and lignite) to a depth of 6,000 feet (1,800 m). (See section on “Extrapolated Bed Map Method,” p. 37; and “Extrapolated Coal Zone Method,” p. 38; see also fig. 4.)

identified resources.—Tonnage estimates for this category of resource include all bituminous coal and anthracite 14 inches (35 cm) or more thick and all subbituminous coal and lignite 30 inches (75 cm) or more thick from the surface to a depth of 6,000 feet (1,800 m) whose location, rank, quality, and quantity have been determined within specified degrees of reliability as demonstrated, measured, indicated, and inferred.

indicated.—Virgin coal that lies between 1/4 mile (0.4 km) and 3/4 mile (1.2 km) from a point of thickness of coal measurement. (See fig. 4.)

indicated marginal reserves.—Tonnage estimates for this category of reserves include those parts of an indicated reserve base that at the time of determination border on being economically producible assuming certain projected economic or technologic changes. The assumed changes and the specific criteria suggesting potential economic profitability should be documented. (See *indicated*, p. 10; and fig. 4.)

indicated reserves.—*Indicated reserves* are estimated from an indicated reserve base by subtracting the assumed tonnage of coal that will be lost-in-mining and indicated marginal reserves. The remaining tonnage—the coal that is assumed will be extracted—is the *indicated reserves*, which must be considered as economically producible at the time of classification. However, facilities for extraction need not be in place and operative. (See *indicated*, p. 10; and fig. 4.)

indicated reserve base.—An *indicated reserve base* is determined by projection of thicknesses of coal and overburden, rank, and quality data from points of measurement and sampling on the basis of geologic evidence using the following criteria: (a) individual points of measurement are bounded by measured coal for 1/4 mile (0.4 km) succeeded by indicated coal from 1/4 mile (0.4 km) to 3/4 mile (1.2 km); and (b) *indicated reserve base* includes anthracite and bituminous coal 28 inches (70 cm) or more thick and subbituminous coal 60 inches (150 cm) or more thick to depths of 1,000 feet (300 m) and lignite 60 inches (150 cm) or more thick to depths of 500 feet (150 m). (See *indicated*, p. 10.)

indicated resources.—Tonnage estimates for *indicated resources* are computed by projection of thicknesses of coal and overburden, rank, and quality data from points of measurement and sampling on the basis of geologic evidence and are assigned to the following categories: (a) individual points of measurement are bounded by measured coal for 1/4 mile (0.4 km) succeeded by 1/2 mile (0.8 km) of indicated coal; and (b) *indicated resources* include anthracite and bituminous coal 14 inches (35 cm) or more thick and lignite and subbituminous coal 30 inches (75 cm) or more thick to a depth of 6,000 feet (1,800 m). The quantity of coal estimated as *indicated resources* is the same as the sum of the indicated reserve base, and indicated subeconomic resources. (See *indicated*, p. 10; and fig. 4.)

inferred.—Virgin coal that lies between 3/4 mile (1.2 km) and 3 miles (4.8 km) from a point of thickness of coal measurement. (See fig. 4.)

inferred marginal reserves.—Tonnage estimates for this category of reserves include those parts of an inferred reserve base that at the time of determination border on being economically producible assuming certain projected economic or technologic changes. The assumed changes and the specific criteria suggesting potential economic profitability should be documented. (See *inferred*, p. 10; and fig. 4.)

inferred reserve base.—An *inferred reserve base* is determined by projection of thicknesses of coal and overburden, rank, and quality data from points of measurement and sampling on the basis of geologic evidence using the following criteria: (a) individual points of measurement are bounded by measured and indicated coal for 3/4 mile (1.2 km) succeeded by inferred coal from 3/4 mile (1.2 km) to 3 miles (4.8 km); and (b) *inferred reserve base* includes anthracite and bituminous coal

28 inches (70 cm) or more thick, subbituminous coal 60 inches (150 cm) or more thick, all to depths of 1,000 feet (300 m), and lignite 60 inches (150 cm) or more in thickness to depths of 500 feet (150 m).

inferred reserves.—*Inferred reserves* are estimated from the inferred reserve base by subtracting the inferred marginal reserves and the coal that is estimated will be lost-in-mining. *Inferred reserves* must be considered as economically producible at the time of determination considering environmental, legal, and technologic constraints. Extraction facilities need not be in place and operative.

inferred resources.—*Inferred resources* are determined by projecting the thicknesses of coal and overburden, rank, and quality data from points of measurement and sampling on the basis of geologic knowledge and are assigned to the following categories: (a) individual points of measurement are bounded by measured and indicated coal for 3/4 mile (1.2 km) succeeded by 2-1/4 miles (3.6 km) of inferred coal; (b) *inferred resources* include anthracite and bituminous coals 14 inches (35 cm) or more thick and lignite and subbituminous coal 30 inches (75 cm) or more thick to depths of 6,000 feet (1,800 m). The quantity of coal estimated as an inferred resource is the same as the sum of the inferred reserve base and inferred subeconomic resources.

lignite reserves.—Tonnage estimates for this class of coal reserves are determined by summing the recoverable quantities of coal in the reserve base and are assigned to the following categories: (a) thickness of coal—5 to 10 feet (1.5 to 3.0 m), 10 to 20 feet (3 to 6 m), 20 to 40 feet (6 to 12 m), and more than 40 feet (>12 m); and (b) thickness of overburden—0 to 500 feet (0 to 150 m). Tonnage estimates for *lignite reserves* may be divided into the lignite A and B groups. Reserves assigned to the lignite class must be considered as economically producible at the time of classification, but facilities for extraction need not be in place and operative.

Discussion: Currently, there are few underground ground lignite mines in the United States. In addition, there are few, if any, lignite strip mines that are removing as much as 300 feet (100 m) of overburden. In order to provide for future technologic and surface mining advances, the maximum thickness of overburden for surface-minable *lignite reserves* and reserve base is set at 500 feet (150 m). It is deemed inexpedient to estimate underground-minable *lignite reserves* and reserve base at depths greater than 500 feet (150 m). (See specific instruction No. 3, p. 34.)